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(54) Title: GROWTH FACTOR COMPOSITIONS, PREPARATION AND USE

(57) Abstract

The invention in growth factor compositions includes: a novel compound which is a separate pure nicked or pure non-nicked species of epidermal growth factor EGF1-48 or its hEGF1-47 or hEGF1-49 congener compound, or a pharmaceutically acceptable salt thereof; a pharmaceutical composition in dosage form comprising an effective amount of the novel compound; and use thereof for treating abnormal cell growth conditions including gastrointestinal/duodenal lesions; and methods of making the pure hEGF species. This unique therapeutic utility is enhanced by the unexpected and heretofore unappreciated structural stability and resistance of the pure species to enzymatic degradation.

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GROWTH FACTOR COMPOSITIONS, PREPARATION AND USE

Field of the Invention

This invention relates to novel growth factor compositions of matter which have anti-ulcer properties. The compositions are protein-like polypeptide hormones or peptides (amino acids in a chain) which are newly found species of the epidermal growth factor (EGF) family. More particularly, the compositions comprise the novel nicked (i.e., broken chain) and non-nicked (intact chain) human EGF: hEGF1-48, and its congeners hEGF1-47, and hEGF1-49. The invention includes pure hEGF1-48, hEGF1-48 in dosage form, treatment methods using hEGF1-48, and methods of preparing pure hEGF1-48.

Background of the Invention

Human EGF is a polypeptide of 53 amino acids with a molecular weight of approximately 6,000 daltons. The amino acid sequence is known. The known hEGF1-53 has a variety of biological/pharmacological effects including stimulation of RNA, DNA and protein synthesis; stimulation of cell growth, and inhibition of gastric acid secretion. EGF has been found to be homologous with another polypeptide hormone urogastrone. The literature occasionally identifies this peptide as EGF-urogastrone, an abstract of which, Abstract 3492, The Merck Index, 11th Ed., 552 (1989) is incorporated herewith by reference.

Patents relating to EGF, urogastrone and fragments thereof described as EGF1-47, EGF1-48 and EGF1-51

include those of Gregory et al. U.S. Patent Nos. 3,883,497; 4,032,633; 4,035,485; and 4,820,690, and the patent of Camble et al U.S. Patent No. 3,917,824.

Biological Activity

The known information about the biological activity of EGF has led to a consensus that human EGF1-53 is the most potent of the EGF-like moieties, with other compounds, including hEGF1-48, being less active.

EGF was initially described by Stanley Cohen and his coworkers. They observed that extracts of salivary glands from rats induced precocious eyelid opening and tooth eruption when administered to newborn rat pups. Subsequently, the peptide EGF was purified from these extracts and characterized. EGF was shown to be a potent mitogen (i.e., an agent causing or inducing mitosis or cell transformation) for a variety of cell types. EGF has both mitogenic and acid suppressive activities in the GI tract.

As indicated, EGF was isolated from salivary glands from which it is secreted into the gastrointestinal lumen (i.e., cavity or channel). It is also secreted into the GI tract from a variety of other sources. This has led to numerous attempts to characterize the activities of EGF in the GI tract.

Reports show that EGF produced a dose-dependent suppression of gastric acid secretion in dogs. Other work has confirmed this acid suppressive activity in several animal species including humans. EGF is less effective as a suppressor of gastric acid secretion than well known acid

suppressive therapies such as histamine-H_2-antagonist or proton pump inhibitors. This suppression of gastric acid secretion follows when EGF is administered by injection (i.e., by parenteral administration) but does not follow when EGF is taken by mouth even at very high doses.

EGF administered into the gastrointestinal lumen (i.e., the stomach or other segment of the GI cavity or channel) does have trophic effects. Thus, increases in tissue mass and DNA synthesis have been reported following intragastric administration and intralumenal infusions of EGF.

The oral administration of EGF has also been shown to promote the healing of experimentally induced gastric and duodenal ulcers which have been induced by any of a variety of agents including acetic acid, laser treatment, cysteamine and indomethacin. More recently, we have found that the mechanism of action for this activity is related to the ability of EGF to accelerate the re-epithelialization (i.e., new repair growth) rate of the induced lesions (FIGURE 1, described below). This is in contrast to acid suppressive therapies which appear to affect portions of the healing process that precede the re-epithelialization phase (FIGURE 2).

Structure/Activity

As indicated above, human EGF is a 53 amino acid peptide which is derived as a result of cleavage from a much larger protein. EGF contains six cysteine residues which form three covalent disulfide bonds.

The structure activity relationship of EGF has been the subject of investigation by a number of laboratories. Molecular forms of EGF-like moieties include EGF1-52, EGF1-51, EGF1-49, EGF1-48, and EGF1-47, as well as a variety of chemically cleaved molecules and molecules with numerous amino acid substitutions. These molecular forms of EGF are reported to be less active than EGF1-53 with respect to mitogenic activity and receptor cell binding activity. With the exception of EGF1-52 none of the fragments of EGF has been evaluated for its *in vivo* activity, probably owing in each case to the prevailing opinion that it would be less efficacious than EGF1-53. Although these molecular forms have been published as having been isolated, none with the possible exception of EGF1-52 has been purified to homogeneity and characterized for homogeneity and identity.

Summary of the Invention

The present invention is based on the discovery of the pure human EGF (hEGF) species, especially as species purified to homogeneity: non-nicked (or intact chain) polypeptides EGF1-47, EGF1-48, and EGF1-49; and the pure human EGF (hEGF) species: nicked (or broken chain) polypeptides EGF1-47, EGF1-48, and EGF1-49.

The invention is thus based on the discovery that conventional means of obtaining EGF1-48 and its congeners EGF1-47 and EGF1-49 (sometimes herein referred to as EGF congeners) -- such as by chemical synthesis, limited

proteolysis of intact EGF, and recombinant microbial techniques -- do not produce the EGF species alone but rather produce the mixed species of the hitherto unnoticed comigrant nicked and non-nicked mixture which by conventional methods including chromatographic techniques have prior to the present invention never been isolated as the separate pure nicked and pure non-nicked species (FIGURE 3).

The invention thus provides the nicked and non-nicked forms of human EGF1-48 and its adjacent EGF1-47 and EGF1-49 congeners also in nicked and non-nicked forms (each as a discrete and separate novel molecular entity). These compounds have unexpected therapeutic utility for the treatment of gastrointestinal lesions. Thus, EGF1-48 and its congeners in pure nicked or pure non-nicked form, each possess unique and unexpected activity.

It is also found that pure EGF1-48 and its pure congeners each in either nicked or non-nicked form have structural stability and resistance to enzymatic degradation (gastric juice and trypsin) which stability and resistance result in unexpected utility for treating gastrointestinal lesions.

Brief Description of the Drawings

FIGURE 1 is a graph showing the dose response of EGF expressed as contracture rate in treatment of canine gastric ulcer; ulcers were induced via laser therapy of the antrum. The ulcer healing process was followed by repeated endoscopic examination during which images of the lesion

were obtained. For each animal, lesion sizes were measured and the rate of reepithelialization was determined as the rate constant for a least squares fit of the lesion sizes over the time course of the experiment;

FIGURE 2 is a schematic of the ulcer phases showing the variation in ulcer size following the initiating event and during pre-contracture, contracture and healing;

FIGURE 3 is a plot of the chromatographic separation profile over time of the hEGF1-48 eluting first as the non-nicked (intact) species and then as the nicked species; the EGF1-48 fraction was isolated and purified from the broth of a fermentation during which expression was induced. This representative chromatogram demonstrated an additional chromatographic separation of the purified hEGF1-48 into the nicked and intact species using an ion exchange resin as described within;

FIGURE 4 is a graph of the dose effect of EGF, relative to the dose effect of hEGF1-48, on indomethacin-induced gastric lesions in the rat, expressed as percent improvement compared to the saline group; rats received an injurious dose of indomethacin (orally) and either saline or the indicated dose (orally) of EGF or hEGF1-48. At 12 hours post dosing, animals were sacrificed and the extent of gastric damage assessed;

FIGURE 5 is a 3-graph set comparing the % AUC for EGF1-49, EGF1-48, and EGF, respectively; samples of each parent peptide, dissolved in human gastric juice were incubated at 37°C. At the indicated times aliquots were

withdrawn and the amount of intact parent peptide was determined as the area under the curve of the A_{214} (absorbance at 214 nanometers) chromatogram;

FIGURE 6 is a composite graph showing over time the relative percentages of unhydrolyzed EGF (hEGF1-48 and EGF1-53) in 1% and 3% trypsin; the experiment is the same as described in Figure 5 except trypsin is the enzyme source;

FIGURE 7 is a gene design diagram for hEGF1-48; showing the nucleotide and corresponding amino acid sequence for the EGF coding region of the EGF expression cassette inserted in the <u>P. pastoris</u> strains; for the strain containing only the hEGF1-48 coding region, the nucleotides coding for residues 49-53 were not included in the cassette;

FIGURE 8 is a graph showing the mitogenesis and competition binding analysis of EGF and hEGF1-48 in Balb 3T3 cells; and

FIGURE 9 is a graph showing the mitogenic effect of EGF and hEGF1-48 in NRK cells.

Detailed Description and Preferred Embodiments

The invention in one aspect comprises a polypeptide selected from hEGF1-48 or its adjacent congener or a pharmaceutically acceptable salt thereof, which polypeptide is pure non-nicked or pure nicked, preferably a polypeptide which is non-nicked, and preferably EGF1-48 of the formula I:

```
H.Asn.Ser.Asp.Ser.Glu.Cys.Pro.Leu.Ser.His.Asp.Gly.Tyr
                       |
          Tyr.Met.Cys.Val.Gly.Asp.His.Leu.Cys
                  25   26                 |
          Ile.Glu.Ala.Leu.Asp.Lys.Tyr.Ala.Cys                    I
                      Tyr.Gly.Val.Val.Cys.Asn
                                      |
                      Ile.Gly.Glu.Arg.Cys.Gln.Tyr
                                    48
                                 HO.Lys.Leu.Asp.Arg
```

A preferred salt is the trifluoroacetate or the acetate salt.

Also preferred is a polypeptide of the formula I which is nicked EGF1-48 or its nicked adjacent congener or a pharmaceutically acceptable salt thereof, preferably nicked between the 25-26 position of the polypeptide chain.

We have found that hEGF1-48 is surprisingly more effective than hEGF1-53 in the treatment of experimentally induced lesions in the gastrointestinal tract (FIGURE 4). A typical result, for example, in the treatment of indomethacin-induced lesions in the rat was an apparent modest reduction (16%) in lesion size (read after 12 hours) in the use of hEGF1-53 at a zero time oral dose of 1.0 nanomoles per Kg. (but without reduction at higher dosage). The size reduction observed was however not statistically different from controls. A typical result in the comparable use of intact hEGF1-48 at various oral doses (0.5, 1.0, 5.0, and 10.0 nmol per Kg) varied from 37 to 46% improvement in lesion size reduction read at 12 hours versus controls, a result that was found to be significant based on t-test analysis. This unique therapeutic utility is enhanced by the unexpected and heretofore unappreciated

structural stability and resistance, as indicated, to enzymatic degradation of nicked and non-nicked EGF1-48 and its congeners. The time course of degradation of pure intact (non-nicked) hEGF1-48, for example, in gastric fluid was found in the typical case to be only slight at one hour, slight to moderate at four hours, and marginally more degraded at 19 hours (FIGURE 5). By contrast, the comparable time course of hEGF1-53 was approaching almost complete degradation at one hour. Similarly, the time course of degradation of intact hEGF1-48 in 1% or 3% trypsin (w/w) was ca. 10% and ca. 25% respectively after four hours. By contrast, the comparable time course of degradation of hEGF1-53 in 1% and 3% trypsin was ca. 50% after one hour and 90-100% after one hour, respectively (FIGURE 6).

As used herein, the term "pharmaceutically acceptable salt" refers to a salt that retains the desired biological activity of the parent compound and does not impart any undesired toxicological effects. Examples of such salts are (a) acid addition salts formed with inorganic acids, for example hydrochloric acid, hydrobromic acid, sulfuric acid, phosphoric acid, nitric acid and the like; and salts formed with organic acids such as, for example, acetic acid, oxalic acid, tartaric acid, succinic acid, maleic acid, fumaric acid, gluconic acid, citric acid, malic acid, ascorbic acid, benzoic acid, tannic acid, pamoic acid, alginic acid, polyglutamic acid, naphthalenesulfonic acids, naphthalenedisulfonic acids, polygalacturonic acid; (b) salts with polyvalent metal

cations such as zinc, calcium, bismuth, barium, magnesium, aluminum, copper, cobalt, nickel, cadmium, and the like; or (c) salts formed with an organic cation formed from N,N'-dibenzylethylenediamine or ethylenediamine; or (d) combinations of (a) and (b) or (c), e.g., a zinc tannate salt; and the like. The preferred acid addition salts are the trifluoroacetate salt and the acetate salt.

As used herein in reference to the EGF species, the term "non-nicked" means the intact polypeptide in which the three disulfide bonds are intact or unbroken and the polypeptide chain is intact. The term "nicked" means that the three disulfide bonds are intact and the polypeptide chain is nicked or broken between at least one pair of adjacent residues of the polypeptide chain such as the 25-26 pair of residues.

The invention in another aspect comprises pharmaceutical compositions in dosage form, preferably for oral administration, containing an effective amount of the described polypeptide (which may be the nicked or non-nicked EGF1-48 or its nicked or non-nicked adjacent cogener EGF1-47 or EGF1-49) and a pharmaceutically acceptable diluent or carrier, for the prevention or management or treatment of diseases of the gastrointestinal mucosa such as erosive or inflammatory diseases in a subject. One uses an amount of the polypeptide that is effective to prevent or manage the disease in the subject or to promote the management or healing thereof. For human treatment, the non-nicked EGF1-48 is to be administered in a dosage regimen, preferably oral, in pharmacologic amounts between

about 0.001 nanomoles/kg and at least about 100 nanomoles/kg per day in pharmaceutically acceptable dosage form. The regimen for nicked EGF1-48 or congener requires a higher dosage in an amount ranging from about 0.01 nanomoles/kg to at least about 10 micromoles/kg per day. Treatment of GI disease conditions may be achieved by the oral route without inhibiting gastric acid secretion in the subject. The invention contemplates pharmaceutical compositions for the prevention or management of or treatment for erosive or inflammatory disease conditions such as erosive or ulcerative esophagitis; inflamed, erosive or atrophic (i.e., being atrophied) conditions of the small or large intestine including but not limited to atrophic gastritis, duodenal ulcers, gastric ulcers, duodenitis, inflammatory bowel disease, ulcerative colitis; and the like. In a preferred embodiment of an oral dosage form and use thereof, an appropriate amount of nicked or non-nicked EGF1-48 or an adjacent congener (as the case may be) is dissolved in aqueous solution, which may include a water soluble cellulose stabilizer such as described in U.S. Patent No. 4,717,717, incorporated herewith by reference, and administered orally. Other oral dosage forms described herein can also be used.

Nicked or non-nicked EGF1-48 or an adjacent congener may be administered therapeutically as part of a common oral formulation which includes a known anti-ulcer agent.

Examples of such anti-ulcer agents known in the art are: the so-called histamine H-2 receptor antagonists,

e.g. cimetidine, ranitidine, and famotidine; gastric specific anti-cholinergic agents such as pirenzepine; prostaglandin E2 analogues such as misoprostol or arboprostil; agents such as sucralfate or carbenoxolone; H^+/K^+ ATPase inhibitors such as omeprazole; and antacids such as aluminum hydroxide/magnesium hydroxide mixtures. For a layman's description of these and other drugs, see Joe Graedon's The New People's Pharmacy, Chapter 5, 134-163, 1985. Bantam Books, Inc., New York, incorporated herein by reference.

The known anti-ulcer agent may be present in the composition in an amount consistent with its known therapeutic activity. Thus, for example, an oral composition containing cimetidine may contain between 100 and 1000 mg. of cimetidine.

The oral pharmaceutical composition may be formulated by means known to the art in the form of, for example, aqueous or oily solutions or suspensions, emulsions, tablets, capsules, lozenges, chewing gums or dispersable powders.

In another aspect, the invention comprises a method for prevention or management or treatment of diseases of the gastrointestinal mucosa including erosive or inflammatory diseases in a subject which comprises administering to the subject an amount of nicked or non-nicked EGF1-48 or its adjacent congener or a pharmaceutically acceptable salt thereof that is effective to prevent or manage the disease in the subject or to promote the management or healing thereof. For human

treatment, the non-nicked EGF1-48 is to be administered in a dosage regimen, preferably oral, in pharmacologic amounts between about 0.001 nanomoles/kg and at least about 100 nanomoles/kg per day in pharmaceutically acceptable dosage form. The regimen for nicked EGF1-48 or congener requires a higher dosage in an amount ranging from about 0.01 nanomoles/kg to at least about 10 micromoles/kg per day. Treatment of GI disease conditions may be achieved by the oral route without inhibiting gastric acid secretion in the subject. The invention contemplates treatment of disease conditions such as erosive or ulcerative esophagitis; inflamed, erosive or atrophic (i.e., being atrophied) conditions of the small or large intestine including but not limited to atrophic gastritis, duodenal ulcers, gastric ulcers, duodenitis, inflammatory bowel disease, ulcerative colitis; and the like.

In still another aspect the invention concerns a method of making non-nicked hEGF1-48 comprising the steps of:

A. growing a human EGF expression strain of the methylotrophic yeast P. pastoris in a fermentation growth medium having a methanol feed, at acid pH, preferably pH 5, for a methanol-sustained growth period resulting in the selectively induced formation of a mature growth medium broth containing yeast expressed non-nicked or intact hEGF1-48 and excluding nicked hEGF1-48, and

B. separating the hEGF1-48 from the broth by means excluding other proteins, especially EGF species other than hEGF1-48, which means excluding other proteins

preferably may include first treating the mature broth with trypsin to selectively degrade the other proteins while leaving intact the hEGF1-48, employing, for example, 1 to 3% trypsin in the broth for one hour at 37°C, followed by HPLC chromatography.

The fermentation is carried out at an acid pH, preferably at pH 5. The methanol feed portion of the fermentation (as described elsewhere herein) is maintained for about 24 to about 40 hours, more preferably for optimum production, about 36 hours. Under these conditions of relatively short methanol induction, we have found surprisingly that the sole EGF product expressed in the broth is the desired non-nicked hEGF1-48. We have found, however, that when the methanol feed portion of the fermentation is carried out for substantially longer periods, i.e., a long methanol induction period (e.g., more than 40 hours), a mixture of both products is obtained: non-nicked hEGF1-48 and nicked hEGF1-48. This result is exemplified by the following methanol-sustained incubation runs, which are typical:

TABLE I

Broth No.	Incubation Time in MEOH	% Nicked
477	110 hrs	50.3
490	40 hrs	2.7

The method employing the short methanol induction is preferred because it facilitates the workup and purification of the desired non-nicked hEGF1-48 in non-salt

or salt form. The separation of non-nicked hEGF from the broth may be carried out by art-recognized means.

In still another aspect, the invention concerns a method of making hEGF comprising the steps of:

A. growing a human EGF expression strain of the methylotrophic yeast P. pastoris in a fermentation growth medium having a methanol feed for a methanol-sustained growth period resulting in the formation of a mature growth medium broth containing a mixture of yeast expressed non-nicked hEGF and nicked hEGF,

B. isolating the hEGF mixture from the broth by steps comprising subjecting the hEGF to column chromatography comprising adsorption on and elution from a strong cation exchange resin under acid conditions to cause the non-nicked hEGF and the nicked hEGF to be eluted as separate eluates respectively, and

C. isolating the non-nicked hEGF and the nicked EGF from the respective eluates. Preferably, the period of methanol-sustained growth is substantially longer than 40 hours, up to 100 hours or longer, as desired, to produce a sufficient quantity of nicked hEGF in the broth mixture.

A preferred resin for column chromatography is a sulfoethylaspartamide resin. We have found surprisingly that while intact and nicked hEGF1-48 have the same retention time on reversed phase HPLC columns, they can be separated on the strong cation exchange column under acidic conditions (FIGURE 3). Under these conditions, nicked EGF1-48 has one extra positive charge as compared with intact EGF1-48. The preferred column is a column of

suitable dimension preferably measuring 4.6 x 200 mm., 300 Angstrom units, 5 microns, employing sulfoethylaspartamide-SCX (available from the Nest Group). For elution, the preferred mobile phases are mobile phase A comprising five millimole phosphoric acid titrated to pH 3 with KOH and containing 25% acetonitrile and mobile phase B comprising mobile phase A that contains 0.3 molar KCl. The preferred elution conditions comprise a linear gradient from phase A to 70% phase B over 45 minutes at 1 ml. per minute. The nicked EGF eluates after the non-nicked EGF and the eluate containing it is lyophilized in pure form. It is nicked between residues 25 and 26 and was found by protein sequencing to be totally nicked. The non-nicked EGF is obtained separately in pure form by lyophilizing the eluate containing it. The invention contemplates the production of any of the species: EGF1-48, EGF1-47, and EGF1-49 by appropriate selection of the producing yeast strain which strain is known or is available by art-recognized means.

Another aspect of this invention is the production of hEGF1-49. The present preferred method includes the steps comprising:

A. Enzymatically treating EGF1-53 by suitable means such as treating with human gastric juice, carboxypeptidase or the like, preferably using human gastric juice as the source of enzyme, for a time sufficient to convert most of the starting material to EGF1-49, about two hours at 37°C in gastric juice; and

B. Separating, preferably by chromatographic procedures, the EGF1-49 from other materials in the

reaction mixture. The enzyme reaction may be stopped or quenched by a variety of means including but not limited to: addition of alcohol or other organic solvent, adjustment of pH above 3.0, or immersion of the reaction vessel in an ice cold bath to reduce the temperature. In the currently preferred embodiment, the chromatographic procedures described for the isolation of EGF1-48 also have been used effectively to purify EGF1-49.

As indicated, the nicked and non-nicked EGF1-48 and congeners are for purposes of the invention preferably derived recombinantly by microbial methods, i.e., by rDNA techniques.

<u>EGF Products By Recombinant Technology</u>

The knowledge of the amino acid sequence of urogastrone allowed design and construction of synthetic genes encoding this peptide, which in turn allowed development of recombinant expression systems. By 1982, the first recombinant expression system for hEGF was reported, utilizing the bacterium <u>E. coli</u> to produce hEGF and yielding 2.3 mg/l of biologically active material. Later, the use of the <u>S. cerevisiae</u> α-mating factor leader sequence to direct secretion of hEGF from <u>S. cerevisiae</u> increased the expression level of a (1-52) form of hEGF to 5 mg/l. More recently, an improved <u>Bacillus</u> expression host has been reported to secrete 240 mg/l of hEGF with no appreciable degradation. With the exception of the <u>Bacillus</u> system, for which no published information on

productivity during scale-up is available, expression levels of hEGF in these recombinant systems are low.

The methylotrophic (requiring methyl alcohol as a nutrient) yeast, Pichia pastoris, has been developed as an improved host for production of recombinant products. Recombinant Pichia pastoris strains advantageously can secrete recombinant proteins in the gram per liter range, can adapt to fed batch or continuous cultivation, have an extremely stable recombinant phenotype (i.e., physical, biochemical and physiological makeup of the yeast), and can maintain high yields over several orders of fermentation scale-up.

What follows is a description of the development and scale-up including the best mode according to the invention to a pilot-plant scale of a process for production and purification of bioactive hEGF, for illustrative purposes usually as the EGF1-48 species that is secreted into the growth medium of a recombinant strain of P. pastoris.

A. Expression and Biochemical Analysis of hEGF Secreted by Pichia pastoris

The alcohol oxidase (AOX1) promoter used to drive heterologous (i.e., different species) peptide synthesis in P. pastoris expression systems is derived from the primary alcohol oxidase gene. Alcohol oxidase catalyzes the oxidation of methanol to formaldehyde and hydrogen peroxide as the first step in methanol metabolism. Development of

a fermentation protocol which induces expression of AOX1-regulated heterologous genes has been previously described.

Briefly, the fermentation consists of three distinct stages. First, the cells are grown on glycerol to accumulate cell biomass while repressing heterologous gene expression. Second, glycerol is fed at a rate which keeps yeast cell growth carbon-limited; the cell mass increases further during this stage but the carbon limitation allows derepression of the methanol metabolic pathway so that the cells begin to adapt to growth on methanol. In the third stage, full expression of the heterologous peptide is induced by introduction of a methanol feed. This protocol was used to induce expression of hEGF from three recombinant strains.

Two *P. pastoris* strains are designated G+EGF817S1 and G+EGF819S4. They contain two and four copies, respectively, of an hEGF expression cassette coding for EGF1-53 integrated into the AOX1 locus of the host strain GS115. A third strain G+EGF206S10 contains six copies of an hEGF cassette coding for EGF1-48 integrated at the H1S4 locus of the host strain GS115. Each expression cassette contains the *P. pastoris* alcohol oxidase (AOX1) promoter and regulatory sequences, DNA sequences coding for the *S. cerevisiae* α-mating factor prepro leader sequence fused to a synthetic gene encoding respectively for hEGF1-53, hEGF1-53, and hEGF1-48 (FIGURE 7); and the AOX1 transcription termination sequence. The transforming DNA also includes the *P. pastoris* HIS4 sequence.

HPLC was routinely used to quantitate the various hEGF species present in cell-free broth from fermentations of strain G+EGF819S4. At the smaller fermentation scales, a series of HPLC profiles typically was taken over 36 hours following methanol induction of EGF expression. At the earliest times a single peptide peak appeared on the chromatogram. By seven or eight hours into the methanol induction phase a second peak was evident and represented the major species present. After 36 hours of methanol induction, a single major peak, which eluted appreciably earlier in the gradient than the two peaks seen previously, was evident. Mass spectral analysis and amino acid analysis identified the three peaks as EGF1-52, EGF1-51, and EGF1-48, respectively. Thus, the EGF was being converted to a progressively shorter peptide over time. We found that the conversion of hEGF from the EGF1-52 to the EGF1-48 form was pH dependent. The conversion pattern described above occurred when the fermentation preferably was conducted at pH 5.

Only one hEGF species, non-nicked hEGF1-47, was produced by strain G+EGF206S10. This strain contains six copies of a DNA sequence encoding hEGF1-48.

B. Biological Activity of hEGF1-48

The recombinant human EGF1-48 produced by the yeast was compared with human EGF1-53 in terms of mitogenic activity in normal rat kidney fibroblasts (NRK-49F) and two murine cell lines. The mitogenic response to EGF is cell line dependent. Maximal stimulation in the rat cell line

is reached at about 10^{-11} M and remains unchanged up to about 10^{-8} M for EGF1-53. For EGF1-48, the effect is observed around 10^{-10} M. The mitogenic response to EGF1-53 in the murine lines occurs at a slightly different concentration and remains near maximal over a much more narrow concentration range (FIGURE 8). The response to EGF1-48 in murine cell lines is about equivalent to the response to EGF1-53 except that the maximal effect occurs at slightly higher concentration and this peak effect is not diminished by increasing the EGF1-48 concentration further in contrast to the response to EGF1-53 (FIGURE 8). Mitogenic evaluation using another murine cell line, CH310T1/2, was substantially similar to the Balb 3T3 data except that EGF1-48 appeared slightly more potent. In all cell lines tested, the maximal response to EGF1-48 is at least as great as that of EGF1-53 (FIGURE 8, FIGURE 9).

C. <u>Fermentation Scale-Up and hEGF Production at 250-Liter Scale</u>

A general consideration in scale-up of fermentation processes is the relatively lower oxygen transfer capacity of larger fermentors compared to laboratory models. This consideration is especially relevant to recombinant <u>Pichia pastoris</u> expression strains. Heterologous gene expression is induced in these strains by the introduction of a methanol feed which is also used for both cell growth and metabolic energy production. Due to the highly reduced state of carbon in methanol relative to carbohydrates, methanol metabolism requires more oxygen per

mole of carbon than does carbohydrate metabolism. The high oxygen requirement for methanol metabolism is often the factor that limits the rate of methanol feed, and thus limits the growth and productivity.

15-Liter Fermentation

Preliminary fermentation investigations showed, and it is a highly significant feature of the invention, that nearly quantitative conversion of hEGF to the EGF1-48 form occurred after 36 hours of methanol feed. The protocol developed for a 15-liter fermentation allowed time for complete conversion of the EGF1-52 form to hEGF1-48 by using a feed rate of 100 ml/h of methanol which filled the fermentor to 11 liters in 42 hours. A typical oxygen utilization of 33 moles O_2/g methanol measured in these fed batch recombinant fermentations is slightly higher than the 30 moles O_2/g methanol reported for continuous fermentations of wild-type P. pastoris. Thus, a feed rate of 100 ml/h methanol at an 8-liter volume would require an oxygen transfer rate of 330 moles O_2 $l^{-1}h^{-1}$. The fermentation can be adapted to fermentors with lower oxygen transfer capacity by reducing the methanol feed rate. To examine the effect of adapting to fermentors with significantly lower oxygen transfer capacity, production of hEGF1-48 was determined at methanol feed rates of 50 ml/h and 25 ml/h in the 15-liter fermentor. These reduced feed rates gave no significant differences in the amount of hEGF1-48 produced, up to about 5 grams per run. However, the time required to produce the 5 grams was 5 days longer at 25 ml/h than at

100 ml/h. Thus, the fermentation process can be readily adapted to any fermentor without loss of yield, although the productivity would be lower in fermentors with less efficient oxygen transfer.

250-Liter Fermentation

EGF production in P. pastoris was scaled to a 250-liter pilot plant fermentor (New Brunswick Scientific, Edison, NJ). A proportional scale-up of the methanol feed would be 1.7 l/h; however, as anticipated, the oxygen transfer capacity initially limited the methanol feed rate to half this rate. Therefore, the operating pressure was increased from 5 to 10 psig and the air sparge was enriched with oxygen to increase oxygen transfer and allow a higher methanol feed rate. These changes allowed an increase in the methanol feed rate to 1.2 l/h. Based on the laboratory studies, the volumetric yield can be maintained at this lower feed rate by running the fermentor 18 hours longer.

From inoculation of the fermentor to harvest, the 250-liter fermentations ran 80 hours. These fermentations consumed 45 liters of methanol and allowed reproducible recovery by centrifugation of clarified broth containing 50 ± 3 grams hEGF1-48. The hEGF1-48 production per liter of methanol feed was the same at the 250-liter scale as that at the laboratory scale.

D. Pilot Scale Purification

At the pilot scale (250-liter fermentor), recovery and purification of hEGF were monitored by a rapid

isocratic HPLC assay for hEGF1-48. The purification was greatly simplified by the fact that hEGF1-48 is by far the predominant peptide in the broth. The HPLC profile of a sample of broth from the end of one of the 250-liter runs showed only one major peptide peak. In the initial recovery step the peptide was removed from 200 liters of clarified broth by adsorption on a reverse phase resin. The adsorption was performed stepwise in a batch mode.

After greater than 90% of the EGF was bound to reverse phase resin, the broth and resin were pumped through a column where the resin was retained by a 10 μ mesh screen. The resin was washed with 0.05 M acetic acid, and the EGF was then eluted from the resin with four to eight liters of eluent to effect a volume reduction from the original broth of almost two orders of magnitude. This rapid volume reduction reduces liquid handling in the later steps. After an adsorption-desorption step on a cation exchange resin to remove colored contaminants, hEGF1-48 comprised more than 85% of the total peptides as determined by analytical HPLC. The hEGF1-48 was then chromatographed by preparative HPLC, the fractions were analyzed by analytical HPLC, and the selected fractions were pooled. The HPLC was loaded with an aliquot containing 6.7 g EGF. The recovery of EGF in the fractions was 100%; the later fractions had higher purity. If the purity criteria were set much higher, for example above 99%, it is likely that the loading of the HPLC would have to be reduced in order to avoid appreciable losses in fractions which could not be pooled.

The acetonitrile introduced into the sample during the HPLC step was removed by binding the EGF to a cation exchange resin and washing with 0.05 M acetic acid. This step also removed most of the trifluoroacetic acid (TFA). TFA was less than 0.1% of the final product which was lyophilized as an acetate salt. The final product obtained was the purified acetate salt of non-nicked hEGF1-48. Before lyophilization, the EGF was sterilized by filtration through a 0.2 μ membrane.

The cation exchange adsorption-desorption procedure used for acetonitrile removal is the same as that which resulted in complete recovery at the decolorization step. On the basis of overall experience with this procedure, a recovery of better than 95% is normal. Thus, in routine operation at the 250-liter scale, the process described is expected to produce batches of more than 30 g of purified EGF.

EXPERIMENTAL PROCEDURES

A. EGF Production Strains

Three different recombinant strains of *P. pastoris* were tested for the production of hEGF. Two strains, as indicated, contained respectively two and four, respectively, copies of an hEGF expression cassette coding for EGF1-53 integrated into the AOX1 locus of the host strain GS115. A third strain G+EGF206S10 contains six copies of an hEGF cassette coding for EGF1-48 integrated at the HIS4 locus of the host strain GS115. Each expression cassette contains the *P. pastoris* alcohol oxidase AOX1

promoter, and regulatory sequences, DNA sequences coding for the S. cerevisiae α-mating factor prepro leader sequence fused to a synthetic gene encoding respectively for hEGF1-53, hEGF1-53 and EGF1-48 (FIGURE 7), and the AOX1 transcription termination sequence. The transforming DNA also includes the P. pastoris H1S4 sequence.

Recombinant hEGF-producing strains of P. pastoris were developed by transformation of the auxotrophic His- Pichia host strain GS115 with vectors containing two, five or six hEGF expression cassettes. The expression vector comprised of two hEGF1-53 expression cassettes, as indicated, is pAO817, and that having five hEGF1-53 cassettes is pEGF819. An expression vector comprised of six hEGF1-48 cassettes is called pEGF206.

Pichia pastoris strain GS115 was the host for transformation with these vectors.

Deposit of Cultures

Viable cultures of the P. pastoris strain GS115 were deposited, under the terms of the Budapest Treaty at the American Type Culture Collection, Rockville, Maryland USA ("ATCC") on August 15, 1987 and were assigned ATCC Accession No. 20864, as documented by PCT Patent Publication No. WO 90/03431, Pub. Date, 5 April 1990, incorporated herewith by reference. Undigested vectors pAO817 and pEGF819 and linearized vector pEGF206 were transformed into GS115 by the spheroplast method [Cregg et al., Mol. Cell. Biol. 5, 3376-3385 (1985) incorporated herewith by reference]. After selection and analysis by

Southern hybridization, the following strains were identified: strain G+EGF817S1 contains two copies of the hEGF1-53-encoding cassette integrated at the AOX1 locus; strain G+EGF819S4 contains four copies of the hEGF1-53-encoding cassette (one copy was lost from the five-copy plasmid vector by recombination during transformation) integrated at the AOX1 locus, and strain G+EGF206S10 contains six copies of the hEGF1-48-encoding cassette integrated at the HIS4 locus.

B. Fermentation Protocols

Fifteen-liter fermentations (in a 15-liter Biolafitte fermentor) were started in a six-liter volume containing four liters of basal salts [52 ml/l 85% phosphoric acid, 1.8 g/l calcium sulfate$\cdot 2H_2O$, 28.6 g/l potassium sulfate, 23.4 g/l magnesium sulfate$\cdot 7H_2O$, 6.5 g/l potassium hydroxide] and 400 g of glycerol. After sterilization, 25 ml of PTM_1 trace salts solution [6.0 g/l cupric sulfate$\cdot 5H_2O$, 0.08 g/l sodium iodide, 3.0 g/l manganese sulfate$\cdot H_2O$, 0.2 g/l sodium molybdate$\cdot 2H_2O$, 20 g/l zinc chloride, 0.02 g/l boric acid, 0.5 g/l cobalt chloride, 65.0 g/l ferrous sulfate$\cdot 7H_2O$, 0.2 g/l biotin and 5.0 ml/l sulfuric acid (conc)] were added, and the pH was adjusted and subsequently maintained at 5.0 by the addition of ammonia gas throughout the fermentation. Excessive foaming was controlled by the addition of 5% Struktol J673 antifoam. The fermentor was inoculated with a volume of 500 ml of an overnight culture (OD_{600}=1 to 4) of the EGF-expressing strain in Yeast Nitrogen Base (YNB), 2%

glycerol, 0.1 M potassium phosphate, pH 6. The dissolved oxygen was maintained above 20% by increasing the air flow rate up to 20 liter/minute, the agitation up to 1000 rpm and/or the pressure of the fermentor up to 1.5 bar during the fermentation.

After exhaustion of the initial glycerol charge, a 50% glycerol feed, containing 12 ml/l PTM_1 trace salts, was initiated at a rate of 120 ml/h; the glycerol feed continued for 6 hours, at which time the methanol feed, 100% methanol plus 12 ml/l PTM_1 trace salts, was started at a rate of 20 ml/h. The methanol feed was increased by 10% each half hour until a feed rate of 100 ml/h was reached. The fermentation was then continued for 25-35 hours.

The conditions for 2-liter and 250-liter fermentors were scaled proportionately from the 15-liter fermentor, except that the final methanol feed rate was limited to the highest rate at which the dissolved oxygen concentration could be maintained above 20% air saturation. In the 2-liter and 250-liter fermentors, the pH was controlled with NH_4OH rather than NH_3, and in the 250-liter fermentor, the air sparge was supplemented with O_2 in some runs.

C. <u>Analytical HPLC</u>

Broth samples to be assayed by HPLC were treated by centrifugation for three minutes in a microcentrifuge to remove cells. Reverse phase HPLC was performed on a Waters Bondapak C18 (0.25 X 30 cm) column with a C18 guard column. Mobile Phase A consisted of 0.1% by weight TFA in deionized

water, and Mobile Phase B was 95% acetonitrile/5% H_2O with 0.1% TFA. The column was equilibrated with a mixture of 80% A and 20% B at a flow rate of 1 ml/min. for 20 minutes before each run.

Each analytical run was 50 minutes. The first five minutes were isocratic at 80% A, 20% B; then the concentration of B was increased linearly over the next 25 minutes to 30% B; and, finally the concentration of B was increased linearly to 55% during the final 20 minutes. UV absorbance was monitored at 210 nm. The different HPLC systems used at several sites gave comparable results.

A shorter analytical HPLC procedure was developed for process control at the pilot scale. The shorter procedure consisted of a ten minute run at isocratic conditions of 72% A, 28% B.

D. Analytical Mass Spectometry

Small amounts of EGF1-47, EGF1-48, EGF1-51, and EGF1-52 were purified from the fermentation broth by reverse phase HPLC. These purified samples were analyzed by fast atom bombardment mass spectometry.

E. Bioactivity Assays

Mitogenic (i.e., cell replication) stimulation by hEGF1-48 was determined in three cell lines by tritiated thymidine uptake. Murine Balb 3T3 cells, C3H10T1/2 cells, and normal rat kidney fibroblasts (NRK-49F) cells were plated into 24 well plates in DMEM (4.5 g/l glucose), phenol red-free, containing 5% Colorado calf serum (Colorado Serum Company). Cells were grown at 37°C in 5%

CO_2 atmosphere. The medium was changed every three days. Cells reached confluence in about three to four days and were allowed to remain at confluence for 24-48 hours before assay. The medium was removed and replaced with DMEM containing 0.1% BSA (Sigma) and 10 U/ml penicillin/streptomycin (Gibco). The cells were serum starved for 22 hours, after which EGF1-53 and EGF1-48 were added in the dose range 0.0 to 30.0 nM, for 24 hours, Dilutions were made from a stock solution of each EGF species whose concentration was determined by amino acid analysis. For maximal stimulation, cells were incubated with 5% calf serum. After the 24 hour incubation period, 100,000 cpm/well of [3H]Thymidine (Amersham) were added, and the plates were incubated at 34•C for 90 minutes. The cells were then washed with 1.5 ml cold PBS, followed by a 20 minute incubation at 4•C with 1 ml cold fixative (50% methanol, 10% acetic acid and 40% PBS). Fixative was aspired off and replaced with 0.4 ml of 1% SDS. The plates were placed on an orbital shaker for about 15 minutes or until the cells detached. The cell suspension was then transferred to scintillation vials and 10 ml scintillation fluid (ScintiVerse BD, Fisher Scientific) were added. Vials were vortexed and placed in a beta counter (LKB 1219, Rackbeta). By these assays intact hEGF-48 had mitogenic activity comparable to that of hEGF1-53.

F. <u>Purification Protocols at 250-Liter Scale</u>

Human EGF-containing broth was separated from cells by centrifugation at a 3 LPM feed rate and 40 second

shoot time (i.e., 40 second interval between discharges) in an Alfa-Laval BTPX205 stacked disc, intermittent discharge, continuous centrifuge at approximately 13,000 x g. The cell concentrate was diluted with deionized water to its original volume and centrifuged as before. The clarified broths from the two separations were combined and further clarified by centrifuging again at a 6 LPM feed rate with a 20 minute shoot time.

Human EGF was removed from the resulting broth by step-wise addition of a reverse phase resin that had been wetted in two volumes methanol (ml/g). Two aliquots of 200 g each (300 g in Run 1), and subsequent aliquots of 300 g each of Vydac 281TPB 15-20 were added to the broth, and the mix was stirred for 15 minutes after each addition. Subsequent to each resin addition, the amount of unbound EGF remaining in the broth was measured by the shorter analytical HPLC procedure. Additional aliquots of resin were added until less than 10% of the starting EGF remained unbound.

The resin was separated from the broth by pumping the resin-broth mixture through a column (30-cm diameter, Amicon) with a 10 μ mesh screen on the bottom support; the top screen was removed prior to the procedure. After the broth was passed through the column, the top screen was replaced, and the resin was washed with 0.05 M acetic acid. The EGF was then eluted with two 4-liter aliquots of 38% ethanol acidified with 3 ml/l glacial acetic acid. The eluate was decolored by loading an aliquot containing not more than 25 g EGF into a column containing six liters of

cation exchange resin (Macrosorb KAX-CM Resin, Sterling Organics) equilibrated in 0.06 mM acetic acid. The EGF was then eluted from the column with 12 liters of 0.3 M ammonium acetate and the column regenerated, as recommended by the manufacturer, with 1 M sodium acetate and 0.1 M sodium hydroxide before decolorizing additional aliquots.

Aliquots of the eluate from the cation exchange column containing not more than 8 g EGF each were loaded onto a two-inch diameter radial compression Waters C18 column for preparative HPLC (Waters Delta prep, Model 3000). The column was washed with a mixture of nine parts A and one part B (90% A, 10% B, the same composition as described for analytical HPLC); EGF was eluted in a 40-minute linear gradient, increasing B from 10% to 25%. Samples (40 ml) were collected from 15 minutes to 30 minutes, and EGF purity was assessed by analytical HPLC. Samples were selected and pooled to give a final purity greater than 95%. To remove acetonitrile, the pooled fractions were loaded onto a 6-liter cation exchange column (Macrosorb KAX-CM resin), and washed with 0.05 M acetic acid until the acetonitrile concentration in the effluent was below 10 ppm, as determined by gas chromatography. EGF was eluted with 0.3 M ammonium acetate. The eluate was filtered through a 0.2 μ filter and lyophilized to a final moisture content of 8%. The product obtained was pure non-nicked hEGF1-48.

The description shows in detail means for producing hEGF and especially hEGF1-48 in pure non-nicked form.

The invention has been described in detail with respect to particular embodiments thereof, but reasonable variations and modifications, within the spirit and scope of the present disclosure, are contemplated by the present disclosure and the appended claims.

References

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Claims

1. A polypeptide selected from hEGF1-48 or its adjacent congener or a pharmaceutically acceptable salt thereof, which polypeptide is non-nicked or nicked.

2. A polypeptide of claim 1 which is nicked EGF1-48 or its nicked adjacent congener or a pharmaceutically acceptable salt thereof.

3. A pharmaceutically acceptable salt of the polypeptide of claim 2.

4. A polypeptide of claim 1 which is non-nicked EGF1-48 or its non-nicked adjacent congener or a pharmaceutically acceptable salt thereof.

5. A pharmaceutically acceptable salt of the polypeptide of claim 4.

6. A polypeptide of claim 2 which is pure nicked EGF1-48.

7. A trifluoroacetate salt or acetate salt of the nicked EGF1-48 of claim 6.

8. A polypeptide of claim 4 which is pure non-nicked EGF1-48.

9. A trifluoroacetate salt or acetate salt of the non-nicked EGF1-48 of claim 8.

10. A polypeptide of claim 6 which is EGF1-48 of the formula I:

```
H.Asn.Ser.Asp.Ser.Glu.Cys.Pro.Leu.Ser.His.Asp.Gly.Tyr
                        |
         Tyr.Met.Cys.Val.Gly.Asp.His.Leu.Cys
                 25   26                  |
         Ile.Glu.Ala.Leu.Asp.Lys.Tyr.Ala.Cys                I
                 Tyr.Gly.Val.Val.Cys.Asn
                                  |
                 Ile.Gly.Glu.Arg.Cys.Gln.Tyr
                           48
                        HO.Lys.Leu.Asp.Arg
```

and which is nicked between the 25-26 position.

11. A pharmaceutical composition in dosage form for prevention or management or treatment of diseases of the gastrointestinal mucosa including erosive and inflammatory diseases, comprising a pharmaceutically effective amount of a polypeptide as in claim 1 and a pharmaceutically acceptable diluent or carrier.

12. A composition according to claim 11 where the EGF1-48 or its congener is nicked.

13. A composition according to claim 11 where the EGF1-48 or its congener is non-nicked.

14. A method for prevention or management or treatment of diseases of the gastrointestinal mucosa including erosive and inflammatory diseases in a subject which comprises administering to the subject an amount of nicked or non-nicked hEGF1-48 or its adjacent congener or a pharmaceutically acceptable salt thereof that is effective to prevent or manage the disease in the subject or to promote the management or healing thereof.

15. A method according to claim 14 where the EGF1-48 or its congener is nicked.

16. A method according to claim 14 where the EGF1-48 or its congener is non-nicked.

17. A method according to claim 14 wherein the non-nicked EGF1-48 or its adjacent congener is administered for human therapy in an oral dosage regimen as a salt or non-salt in pharmacologic amounts between about 0.001 to about 100 nanomoles per kilogram per day.

18. A method according to claim 14 wherein the nicked EGF1-48 or its adjacent congener is administered for human therapy in an oral dosage regimen as a salt or non-salt in pharmacologic amounts between about 0.01 to about 10 micromoles per kilogram per day.

19. A method according to claim 14 where the treatment comprises administering to a human the non-nicked EGF1-48 or the acetate salt thereof.

20. A method of making non-nicked hEGF1-48 comprising the steps of:

A. growing a human EGF expression strain of the methylotrophic yeast P. pastoris in a fermentation growth medium having a methanol feed for a methanol-sustained growth period resulting in the selectively induced formation of a mature growth medium broth containing yeast expressed

non-nicked or intact hEGF1-48 and excluding nicked hEGF1-48, and

B. separating the hEGF from the broth by means excluding other proteins including EGF species other than hEGF1-48.

21. A method according to claim 20 where the fermentation is carried out at pH 5 with a methanol feed for a period optimizing the expression of non-nicked hEGF1-48.

22. A method according to claim 20 where the fermentation is carried out with a methanol feed that is terminated before the expression of nicked hEGF.

23. A method according to claim 20 where the methanol feed is maintained for 36 hours.

24. Non-nicked human EGF1-48 produced by the method of claim 20.

25. A salt of non-nicked EGF1-48 produced by the method of claim 20.

26. A method of making hEGF1-48 comprising the steps of:

A. growing a human EGF expression strain of the methylotrophic yeast <u>P. pastoris</u> in a fermentation growth medium having a methanol feed for a methanol-sustained growth period resulting in the formation of a mature growth medium broth

containing a mixture of yeast expressed non-nicked and nicked hEGF1-48,

B. isolating the hEGF1-48 from the broth comprising subjecting the hEGF1-48 to column chromatography comprising adsorption on and elution from a strong cation exchange resin under acid conditions to cause the non-nicked hEGF1-48 and the nicked hEGF1-48 to be eluted as separate eluates respectively, and

C. isolating the non-nicked hEGF1-48 and the nicked EGF1-48 from the respective eluates.

27. The method of claim 26 where the period of growth is substantially longer than 36 hours.

28. The method of claim 26 where said resin comprises sulfoethylaspartamide resin.

29. The method of claim 26 employing mobile phase A comprising five millimole phosphoric acid titrated to pH 3 with KOH and containing 25% acetonitrile and mobile phase B comprising mobile phase A that contains 0.3 molar KCl.

30. The method of claim 29 where the elution conditions comprise a linear gradient from phase A to 70% phase B over 45 minutes at 1 ml. per minute.

31. Non-nicked hEGF1-48 produced by the method of claim 26.

32. Nicked hEGF1-48 produced by the method of claim 26.

33. A method of making hEGF1-49 comprising the steps of:

A. treating hEGF1-53 by reaction with enzyme to convert substantially all of said hEGF1-53 to hEGF1-49;

B. quenching the enzyme reaction; and

C. separating the thus produced EGF1-49 from the reaction mixture and purifying the same.

34. The method of claim 33 where the enzyme is human gastric juice.

35. The method of claim 33 where the reaction is carried out at 37℃ for two hours and is then quenched.

36. The polypeptide hEGF1-49 produced by the method of claim 33.

37. A method according to claim 20 where said means excluding other proteins comprise treating the mature broth with trypsin to selectively degrade said other proteins while leaving intact the hEGF1-48, and separating the intact hEGF1-48 from the broth by means comprising chromatographic means.

38. hEGF1-48 produced by the method of claim 37.

39. A salt of hEGF1-48 produced by the method of claim 37.

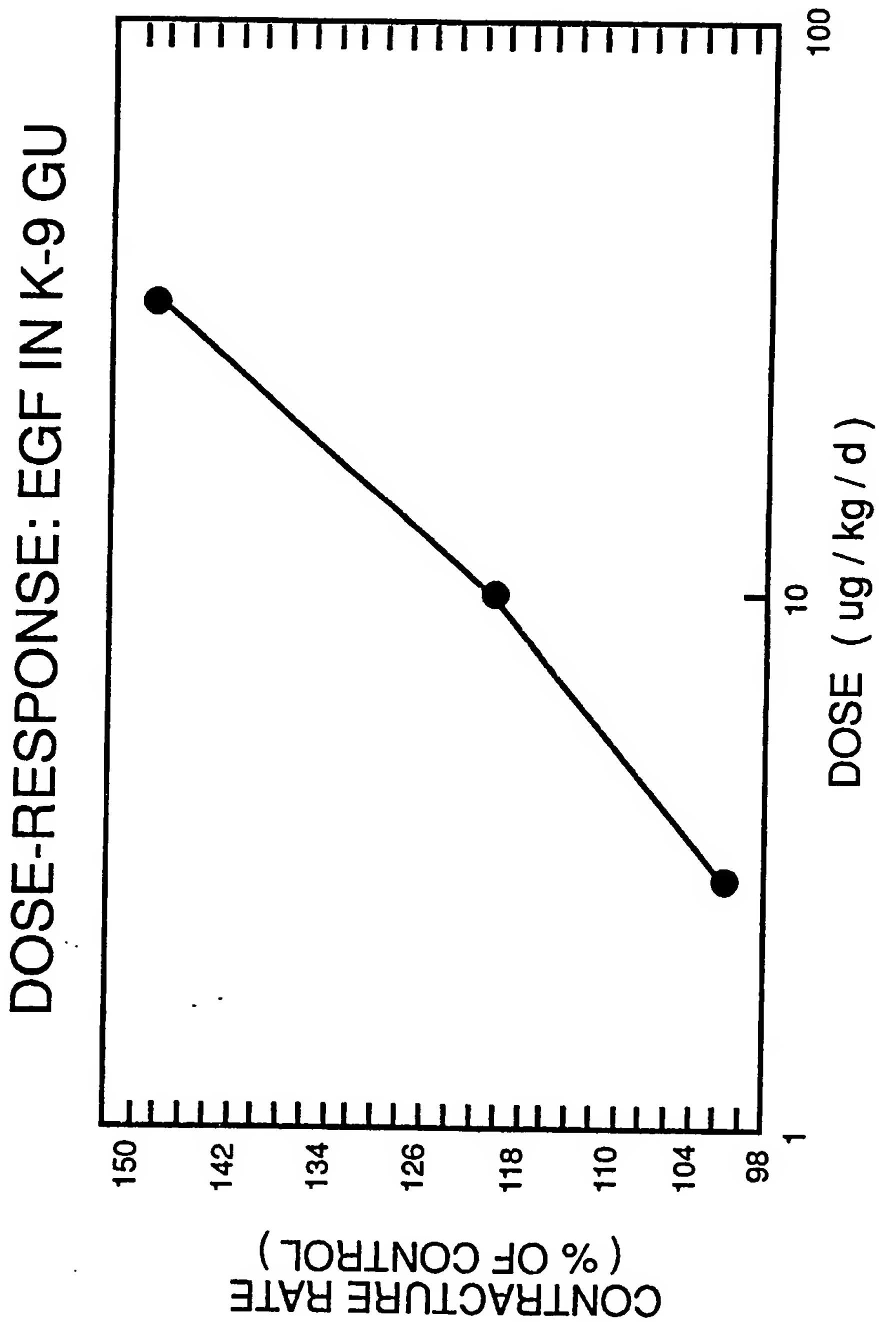

DOSE-RESPONSE: EGF IN K-9 GU
CONTRACTURE RATE
(% OF CONTROL)
150
142
134
126
118
110
104
98
1
10
100
DOSE (ug / kg / d)

FIG - 1

SCHEMATIC OF ULCER PHASES

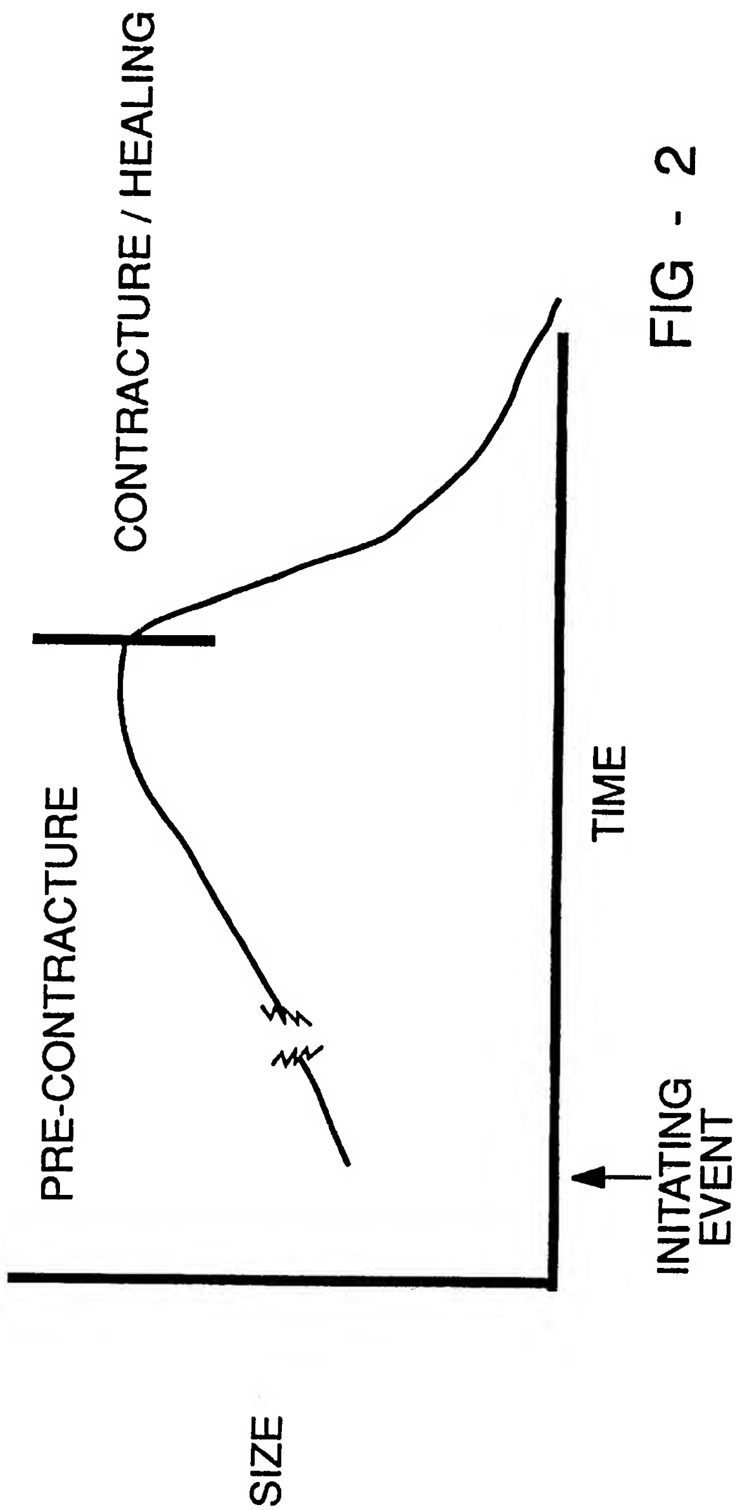


FIG - 2

SEPARATION OF EGF 1 - 48 FRACTION

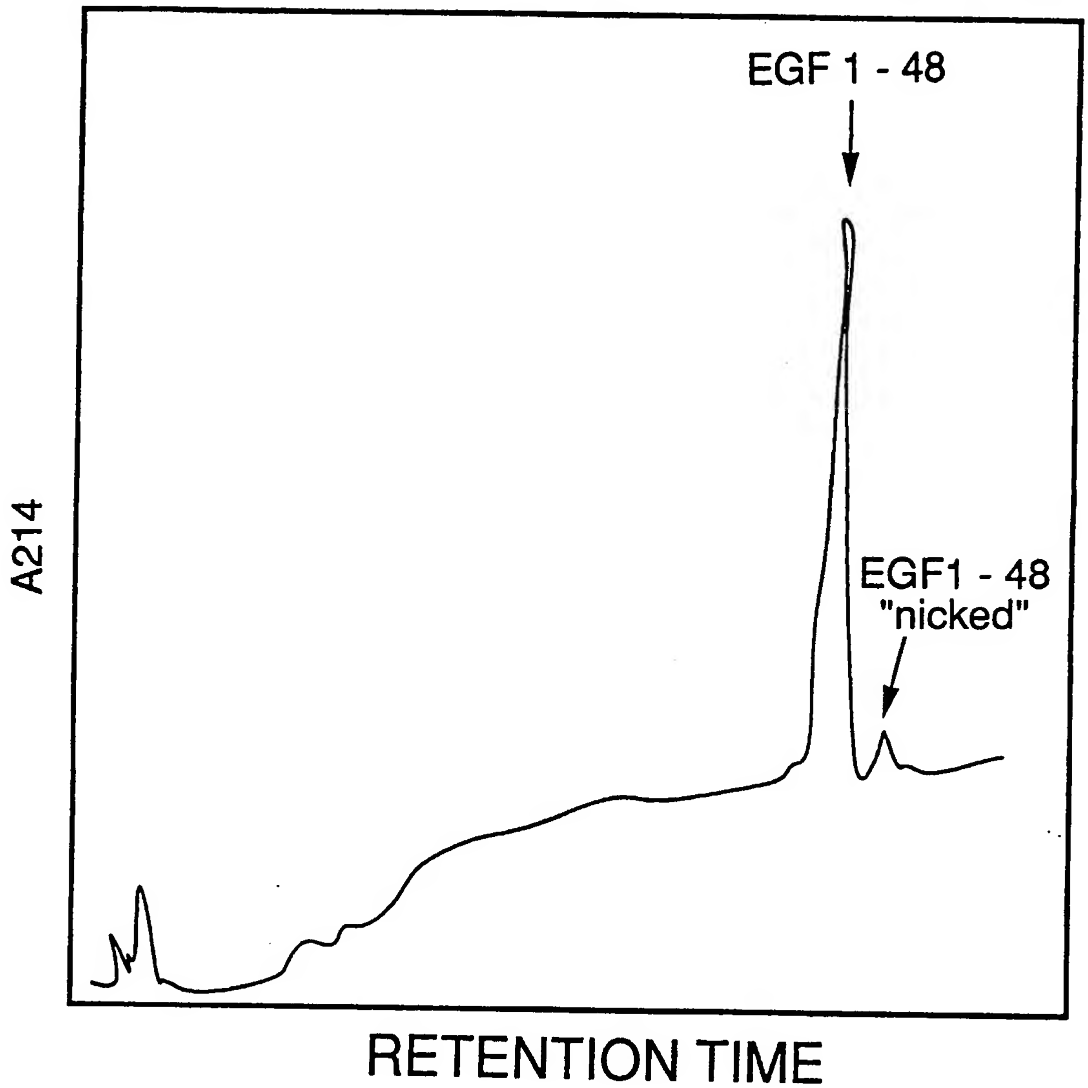


FIG - 3

Effect of EGF and EGF1-48 on Indomethacin-Induced Gastric Lesions in the Rat (12h post indomethacin)

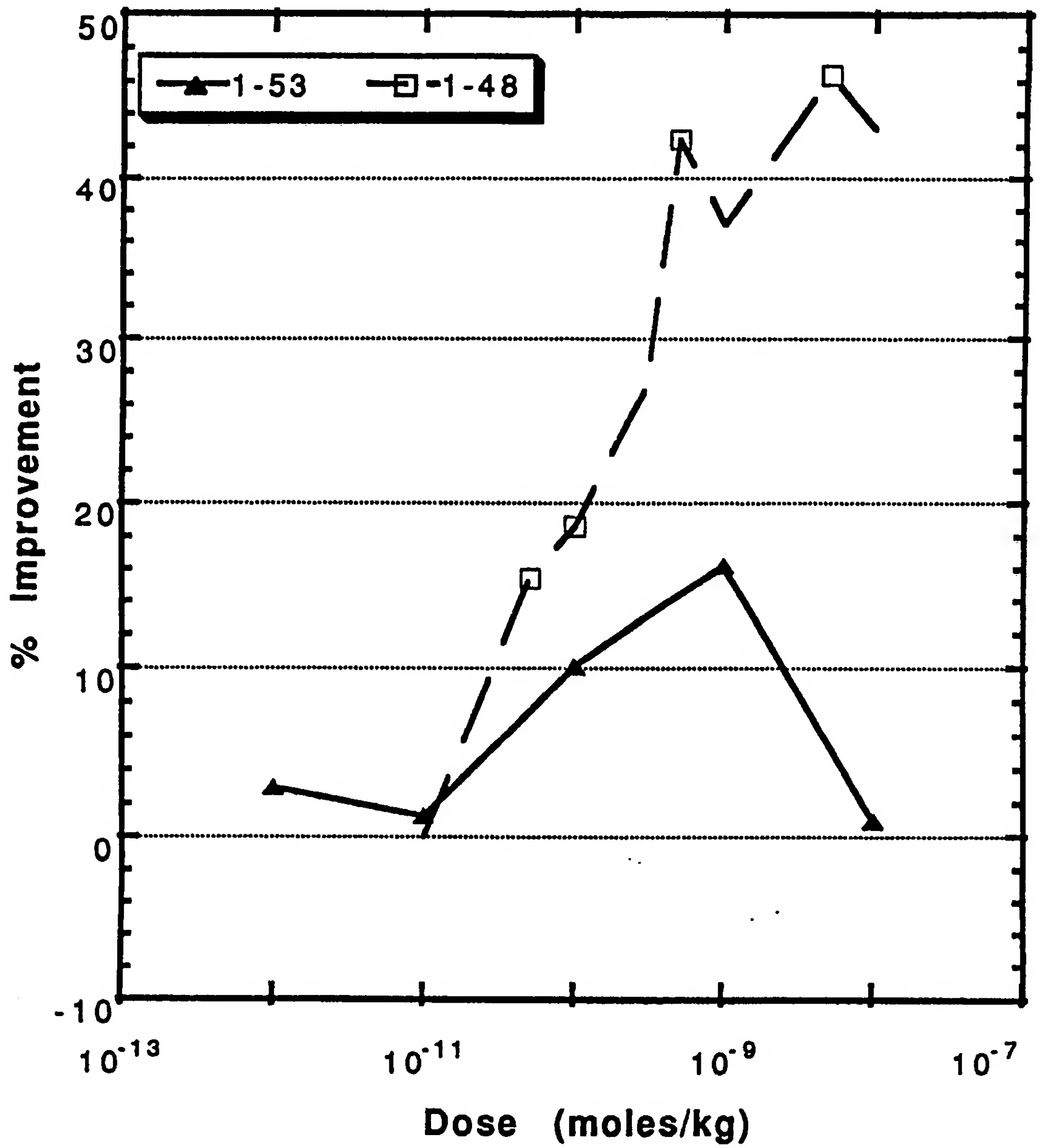


FIG - 4

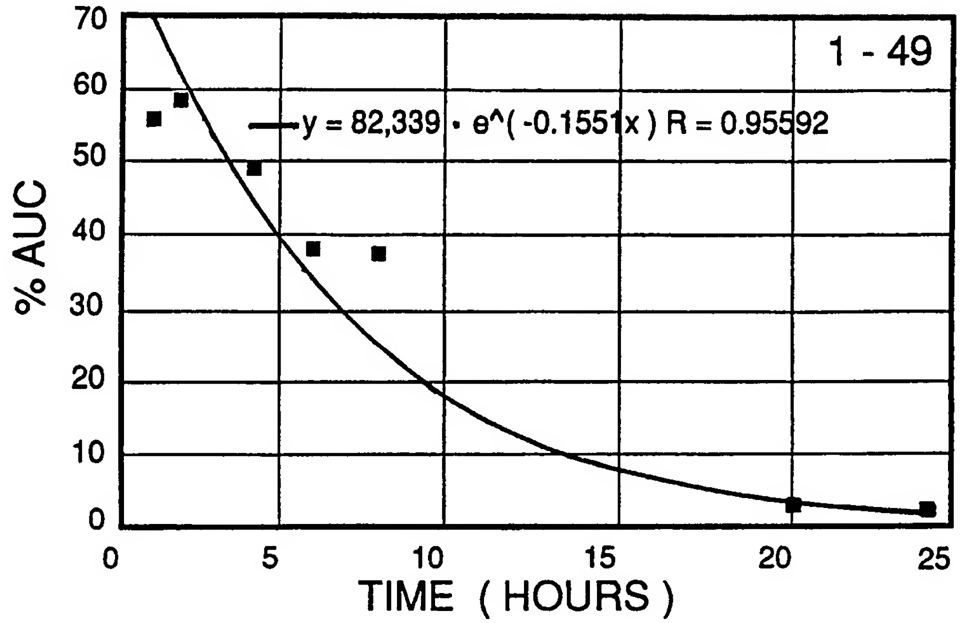

1 - 49
y = 82,339 • e^(-0.1551x) R = 0.95592
% AUC
70
60
50
40
30
20
10
0
0
5
10
15
20
25
TIME (HOURS)

FIG - 5A

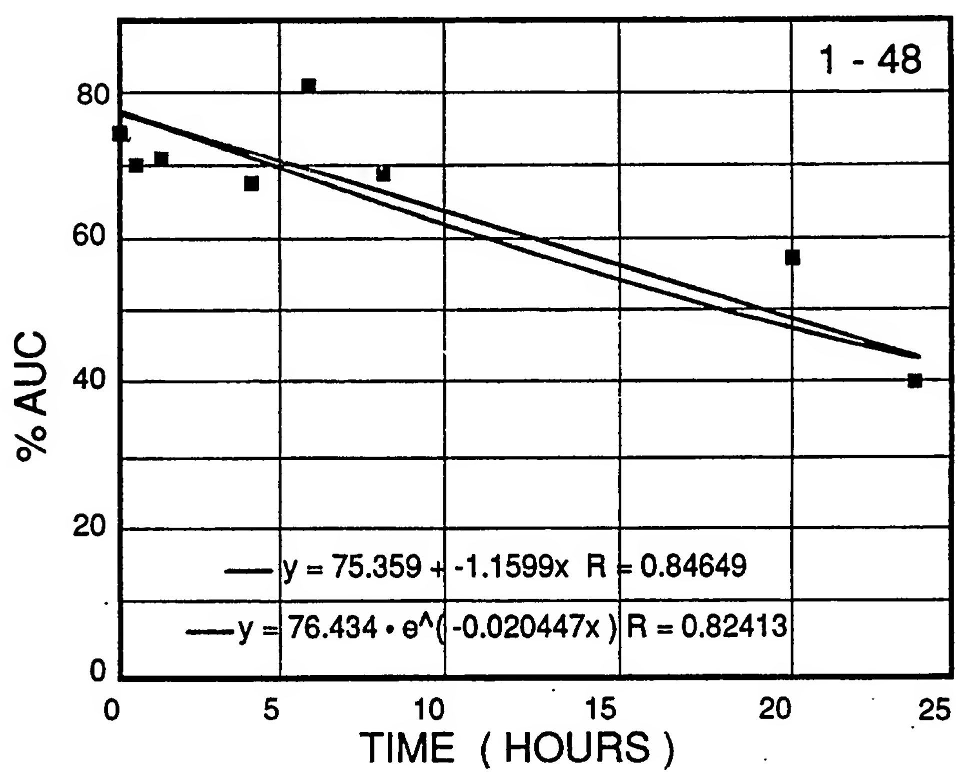

1 - 48
y = 75.359 + -1.1599x R = 0.84649
y = 76.434 • e^(-0.020447x) R = 0.82413
% AUC
80
60
40
20
0
0
5
10
15
20
25
TIME (HOURS)

FIG - 5B

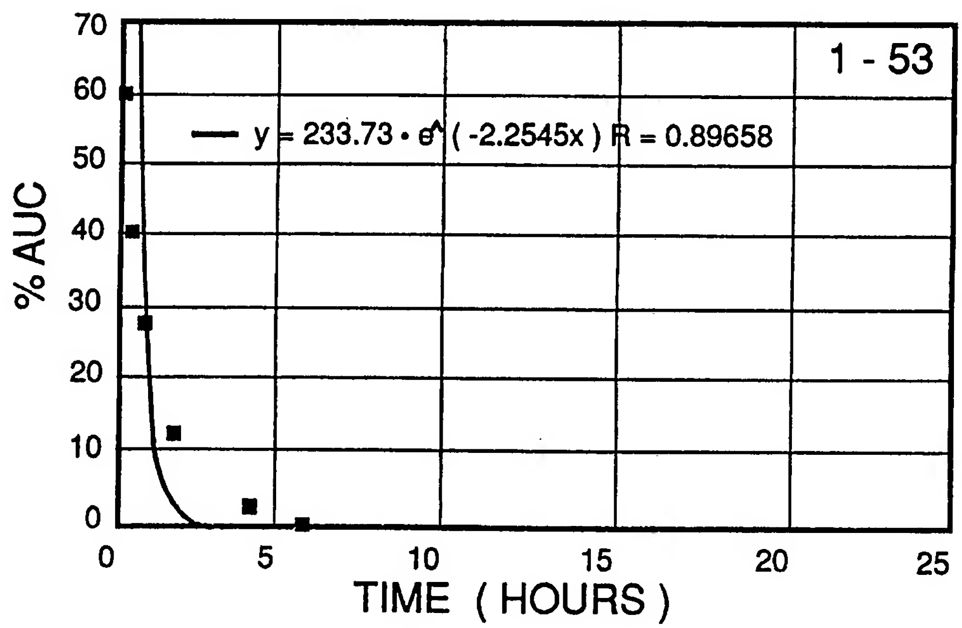
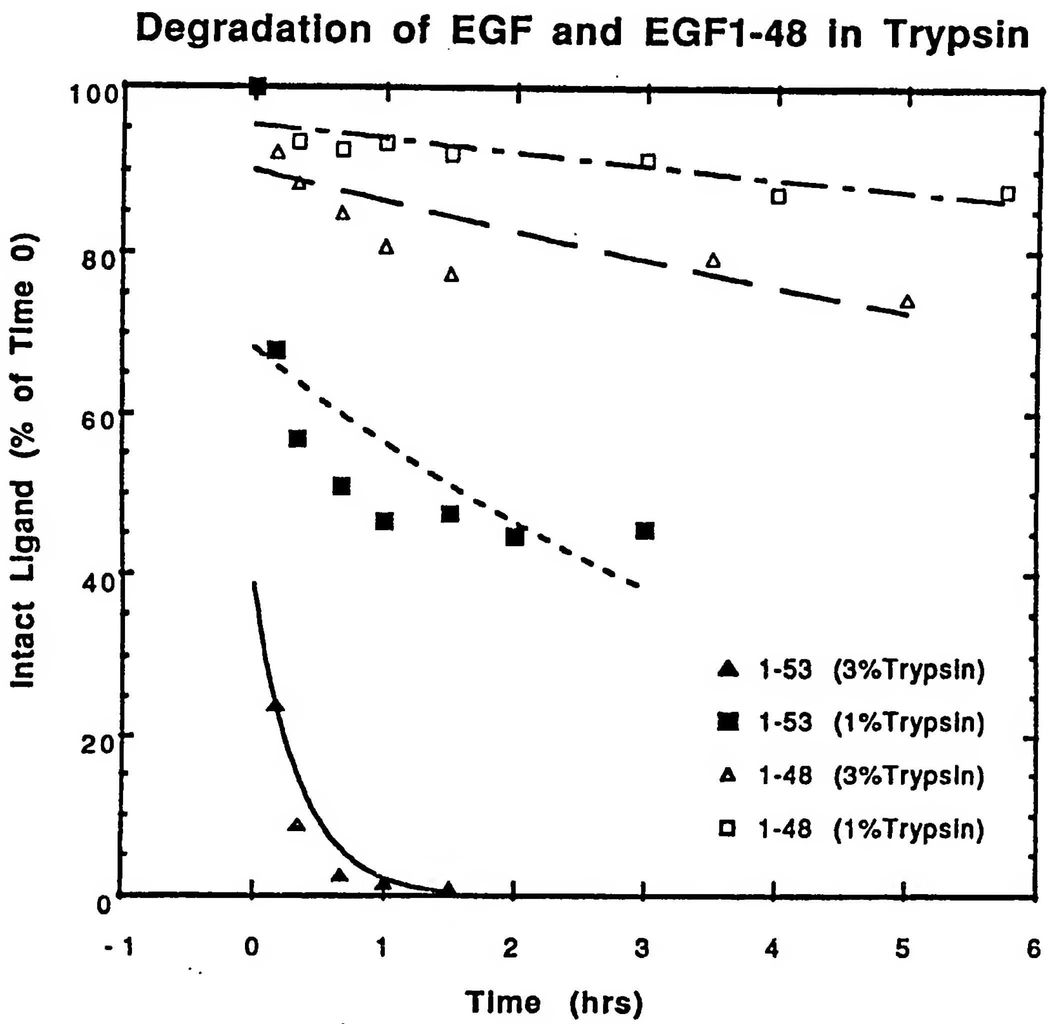

70
60
50
40
30
20
10
0
% AUC
1 - 53
y = 233.73 • e^(-2.2545x) R = 0.89658
0
5
10
15
20
25
TIME (HOURS)

FIG - 5C



——y = 38.728 * e^(-2.854x) R= 0.91127

······y = 68.191 * e^(-0.19238x) R= 0.70809

— -y = 89.97 * e^(-0.043107x) R= 0.77854

—·-y = 95.385 * e^(-0.017442x) R= 0.82978

FIG - 6

Gene Sequence and resulting Amino Acid Sequence for the EGF Coding Region in the EGF Expression Cassette.

AAT TCC GAT AGC GAG TGT CCT CTG AGT CAC GAT GGT TAC
Asn Ser Asp Ser Glu Cys Pro Leu Ser His Asp Gly Tyr
residue# 1 5 10

TGT CTA CAT GAC GGC GTC TGT ATG TAT ATT GAG GCT CTA GAC
Cys Leu His Asp Gly Val Cys Met Tyr Ile Glu Ala Leu Asp
15 20 25

AAG TAC GCG TGT AAT TGC GTT GTT GGC TAC ATC GGT GAG CGT
Lys Tyr Ala Cys Asn Cys Val Val Gly Tyr Ile Gly Glu Arg
30 35 40

TGT CAG TAT CGT GAT CTG AAA TGG TGG GAA CTT CGT TAA
Cys Gln Tyr Arg Asp Leu Lys Trp Trp Glu Leu Arg
45 48 50 53

FIG - 7

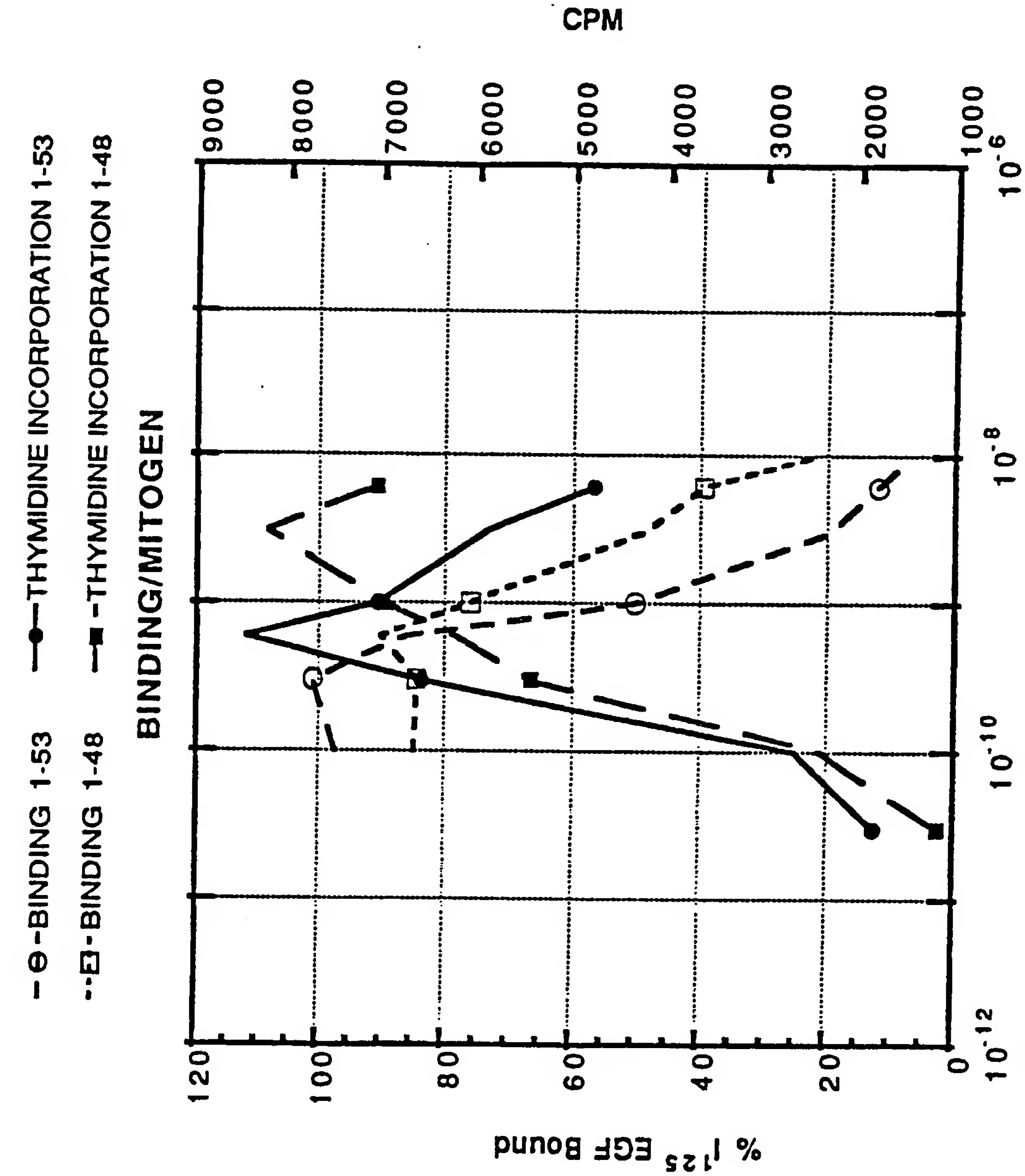

BINDING/MITOGEN
-θ- BINDING 1-53
--⊡- BINDING 1-48
—●— THYMIDINE INCORPORATION 1-53
-■- THYMIDINE INCORPORATION 1-48
CPM
9000
8000
7000
6000
5000
4000
3000
2000
1000
120
100
80
60
40
20
0
% I125 EGF Bound
10^{-12}
10^{-10}
10^{-8}
10^{-6}
Concentration (M)

FIG - 8

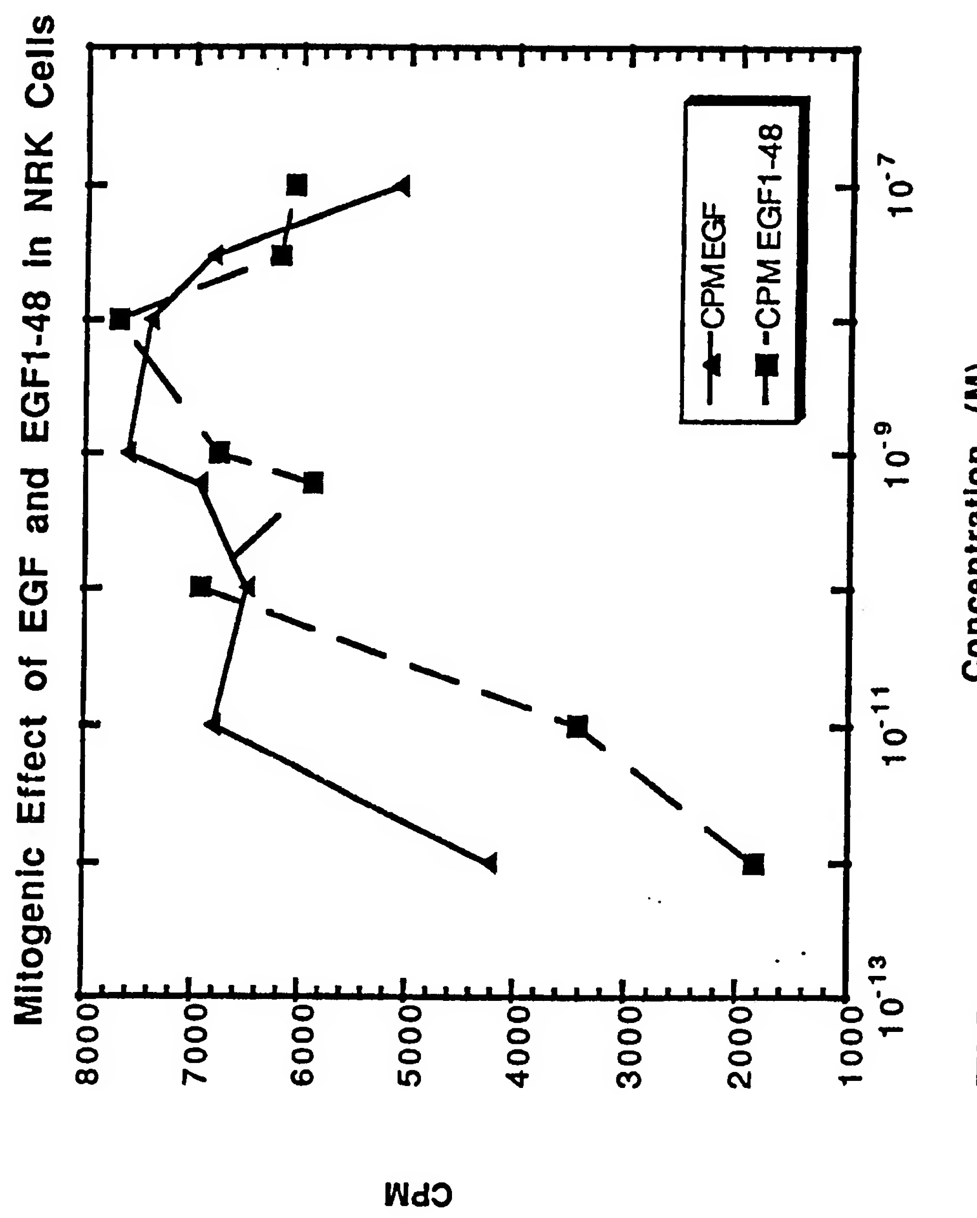

Mitogenic Effect of EGF and EGF1-48 in NRK Cells
CPM
8000
7000
6000
5000
4000
3000
2000
1000
10^{-13}
10^{-11}
10^{-9}
10^{-7}
Concentration (M)
CPMEGF
CPM EGF1-48

FIG - 9

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/05396

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC
IPC(5); A61K 37/36; C12P 21/02; C07K 15/00
US. Cl: 435/69.1, 172.1; 530/324, 399; 514/012; 435/69.6

II FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
US	435/69.1, 69.6, 172.1; 530/324, 399; 514/012

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

Chemical Abstracts and APS

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X Y	US, A, 3917,824 (Camble et al) 04 November 1975, see entire abstract and column 1, lines30-41.	1,4,5,8,11,12, 14-16,24,31,38 9,14,16,17,19, 25,39
A	British Medical Bulletin, vol. 45, No. 2, issued 1989, Antony W. Burgess, Epidermal growth factor and transforming growth factor α, pages 401-424, note particularly the paragraph bridging pages 415 to 416.	1-39

* Special categories of cited documents: [10]
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
20 December 1991	10 JAN 1992
International Searching Authority	**Signature of Authorized Officer**
ISA/US	Diane Moffett for Fatemeh Moezie

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FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

X	WO, A, 90/03431, (Brierley et al) 05 April 1990, note the abstract.	1,2,5,8,11,12, 14,16,18,20,24, 25,26,31

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers , because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers .. .. , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

3. ☐ Claim numbers__________, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

See attachment

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

PCT/US91/05396

Attachment to PCT/ISA/210

This application contains claims drawn to the following distinct inventions:

I. Claims 2, 3, 6, 7, 10. 12, 15 and 32 are drawn to a hEGF 1-48 nicked polypeptides. their salts, pharmaceutical compositions, methods of treatment and the first appearing method of preparing the polypeptide.

II. Claims 4, 5, 8, 9, 13, 16. 20-25. 31 and 37-39 are drawn to hEGF1-48 non-nicked hEGF1-48 polypeptides. their salts. pharmaceutical compositions. methods of treatment and the first appearing method of preparation.

III. Claims 33-36 are drawn to a method of preparing hEGF1-49 and the product(s) made therefrom.

Claims 1. 11. 14. 17-19 and 26-30 link inventions I and II.

The inventions are distinct. one from the other. because of the following reasons:

The inventions are separately classified and require different fields of search. Further, the art anticipating of one invention would not render any of the other inventions obvious. absent ancillary teachings. It would be an undue burden to examine all of the inventions in one application.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to F. Moezie whose telephone number is (703) 308-3400.

Any inquiry of a general nature or relating to the status of this application should be directed to the Group receptionist whose telephone number is (703) 308-0196.